

A METHOD OF STRATIGRAPHIC CORRELATION USING EARLY CRETACEOUS MIOSPORES

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ABSTRACT. Spores of the *Cicatricosisporites* group are used in correlation between the outcrop Hastings Beds and the Lower Wealden of the Warlingham Borehole, Surrey. Published species are not used, and the fossils selected are described instead in terms of *biorecords* and *events*, both of which terms are defined. There is a brief discussion of the relationship of these biorecords to published taxa. The method of use of the fossils is chosen to favour (a) correlation on a fine scale, (b) easy inclusion of extensions of the observations to refine the correlations, and (c) storage and retrieval of essential data as free as possible from points of interpretation, which should be separately labelled and stored. The material is presented in slightly extended form so that the method itself may be criticized and improved. Some of the specific difficulties of handling *Cicatricosisporites* spores are illustrated and discussed.

By far the most numerous fossils in the Lower Wealden rocks of southern England are dispersed miospores, and we believe that there has been a failure hitherto to use them, or other spores of similar age, successfully in any fine stratigraphic correlations (see Hughes 1958, and several other authors). Spores have served to define fairly large time divisions on the scale of an 'Age (Stage)', but this does not represent an improvement on stratigraphy using any other type of (less common) fossil. It had become apparent to us that much additional work was not yielding results in terms of stratigraphic refinement, and we now believe that this was due to a failure of method rather than to any lack of evolutionary manifestation in these plant-organ fossils. We have suggested a new approach (Hughes and Moody-Stuart 1967*b*) and we attempt here to develop it further. As we have found it necessary to reject certain current practices as unprofitable, we wish to avoid misunderstanding by stating briefly the reasons for this action, in a list of points numbered for reference in discussion:

1. In accepting the stratigraphic approach implicit on the report of the Geological Society of London's Stratigraphical Code Subcommittee (George *et al.* 1967), and developments from it (Hughes, Williams, Cutbill, and Harland 1967, 1968), we see *reference-points* as the first essential for both precision and unambiguous communication.

2. An *event* (stratigraphic) is an item of geologic information relatable (or potentially so) to the general evolutionary state of the earth, and based in a rock sample or in a general attribute (to include metamorphism, etc.) of some named rocks.

3. The identification of events is artificial and arbitrary, being dependent mainly on the accidents of collection. In stratigraphy of sedimentary sequences, an event is any character raised from a rock sample that is as closely located as possible. The borehole samples used in this paper are mainly located to 1 ft. in depth, which seems more than adequate at present but may not be so in twenty years time. The average stratigraphic spacing of events concerned with fossil information should be at most one-quarter (de Jekhowsky 1958) and probably one-tenth of the general size of scale division that is sought.

4. Stratigraphic *correlation* of a newly described 'event' (in a 'new' section), with a standard (already described) reference scale of 'events', consists of a *pair* of decisions.

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Each of the two similar decisions is: whether the newly described event represents a time before or after a selected reference scale event. The 'bracket' so obtained may be fine or coarse but is always theoretically capable of refinement, given new observations or interpretations. The correlation of whole rock sequences, however elaborately expressed, consists essentially of these primary paired decisions.

5. Events cannot be equated in time, but only ordered. The purely mental process of grouping events into some kinds of biostratigraphic zones, usually to achieve equation between sequences, is equivalent to the employment of a blunt instrument in correlation that cannot be operated successfully within the limits of the size range of its bluntness.

6. Stratigraphic zones are unacceptable to us as tools because (a) they cannot as abstractions be closely enough defined, and (b) they are based on the idea of equation in stratigraphy which is either too crude or is even wrong in concept. Excluded from this criticism is the chron (George *et al.* 1967) which is simply a rock-defined minor time division in a standard reference section.

THE PALAEOONTOLOGIC PROBLEM

7. In predominantly non-marine strata such as the English Wealden, the frequently occurring fossiliferous palynologic samples may well contain assemblages with species from 25 distinct miospore 'genera'. These species have been erected and expanded by many authors on purely morphographic principles, usually with a reconnaissance description in mind; as a result they tend to have relatively long ranges. They have proved difficult to 'split' further on purely morphographic grounds, and because of general palaeontologic tradition against the practice there has been a reluctance to add any explicit stratigraphic limits to the diagnoses of the 'splits'.

8. In studying other comparable palynologic problems for possible solutions, it is difficult to assess the unpublished achievements in oil exploration. The successful German technique used in the study of Tertiary Brown Coal is more akin to Pleistocene work in its limited geographic and stratigraphic scale. Most of the many papers on the West European Carboniferous do not appear to aim at or to achieve fine stratigraphy; particularly interesting in this respect is the major work of Smith and Butterworth (1967) which, however, is unusual in being restricted to the one facies group of the coals, and also unusual in providing so much well-presented basic data, clear of its interpretation. Although much palynology is still in the reconnaissance phase of development, we have not found any solution from study of work that is already further advanced.

9. There is clearly a temptation to abandon any accepted species concept (cf. Shaw 1964, p. 220) as being too 'blunt' (see para. 5 above), and to attempt some total description of the sample assemblage that could be compared with others by machine methods. Although such description would be difficult to accomplish even on a 'module' basis without detailed preliminary interpretation, the main factors that appear to rule it out for the present are palynologic facies (see Hughes and Moody-Stuart 1967a) and variable preservation of miospores. The mere numbers of fossils available will eventually make machine handling of data essential, but understanding, particularly of the chemical aspects of preservation, is in our opinion insufficiently advanced to make this at all profitable.

10. Behind such considerations is the usual economic problem in biologic descriptions. Whatever observations are made in erecting a scheme, and whatever further work is

necessary to make use of it, must not involve more skilled or semi-skilled man-hours than the information is judged to be worth now or in the immediate future.

PROPOSED METHOD

11. Since variation in land-life forms, at least since the Devonian period, is assumed to have been discontinuous on the same basis as for observed recognition of extant species, it seems wiser to use this assumption rather than to ignore it (as implied in para. 9 above).

12. As a preliminary, then, to consideration of events for correlation, we intend to make in each appropriate miospore group (taken to mean approximately the current miospore genus) a set of fully documented '*biorecords*', primarily for local use in our standard stratigraphic succession (regional standard in the sense of George *et al.* 1967), which will be the Warlingham Borehole. These will approximate to species as currently used but will be outside the Rules of Nomenclature; they will instead be subject to special rules that we devised for species (Hughes and Moody-Stuart 1967*b*, pp. 348–9) but here applied to biorecords, in that they can only ever be modified (emended) by use of topotype material.

13. A *biorecord* is defined as a conceptual taxon, based on specimens from one sample or locality that are judged to have a normal distribution of continuous variation. A palynologic biorecord has a basis in not less than 100 topotype specimens. Should a biorecord prove unsatisfactory in use, it can be replaced without formality by another from the same or another sample; it can also overlap the variation of another to any degree. There is no question of priority, only one of use or discard; each biorecord bears a unique author's serial number.

14. We present here biorecords for all the kinds of *Cicatricosisporites* that we have seen in the Lower part of the Wealden of the Warlingham No. 1 Borehole (Surrey, England) from 2,040 to 1,740 ft. depth. Work on the Upper part of the Wealden, and studies on other genera such as *Aequitriradites*, *Trilobosporites*, etc., are not yet complete.

15. The events used in this paper are thus composed solely of information on *Cicatricosisporites* miospores. The occurrence of these spores in each event sample is expressed as percentages of types that are judged by eye and by measurement as distinct, and are recorded (using measurements) by graded comparisons (see Hughes and Moody-Stuart 1967*b*, p. 353) with the appropriate biorecord.

16. Events, with some additional biorecord material, based on samples from the coastal outcrop of the Fairlight Clay near Hastings are correlated with those of the borehole regional standard. Correlation with a main marine standard succession is not attempted in this paper.

17. An attempt has been made to ensure that all data generated here can be assessed and stored without further attention from a palynologist. Both these arrangements and the general method are described more fully than would normally be necessary in the hope that the principles may be discussed.

18. Although it is only partly relevant to our stratigraphic purpose, we believe that for dispersed spores our biorecord (based on topotype material only) gives a much better opportunity than does any orthodox fossil species of an approach to the spores actually produced by a once-living plant population. From our studies so far we are strongly of

the opinion that land plant evolution will, with the help of palynology, soon be demonstrable in quite fine detail; the old view that land plants evolved slowly was largely due to the obscuring effect of unthinking adherence by palaeontologists to a Linnéan system of nomenclature that had been devised and developed for living organisms with verifiable genetic limits.

ESTABLISHMENT OF A BIORECORD

The biorecord is not in essence different from a palaeontologic species at the stage of description by its originator, but differs in the use that can subsequently be made of it. The process of selection of suitable material presents the same difficulties as with species, but almost no literature search is obligatory, and no awkward description priorities need be considered. In the current case, the sequence of work appears to be:

1. Reconnaissance of as many samples of the standard sequence as possible to select suitable samples for biorecords satisfying the following requirements: (a) adequate preservation; (b) adequate ease of obtaining 100 specimens; (c) facies that is unlikely to have modified significantly the part of the assemblage concerned, i.e. to have removed part of the size variation; (d) as early as possible in the stratigraphic 'range' of the form concerned; (e) useful biorecord, i.e. spore type seen elsewhere. The difficulty is to achieve these aims safely without too great an expenditure of time.

2. Using the selected sample, record the slide position of each specimen of *Cicatricosisporites* and record its major character as follows:

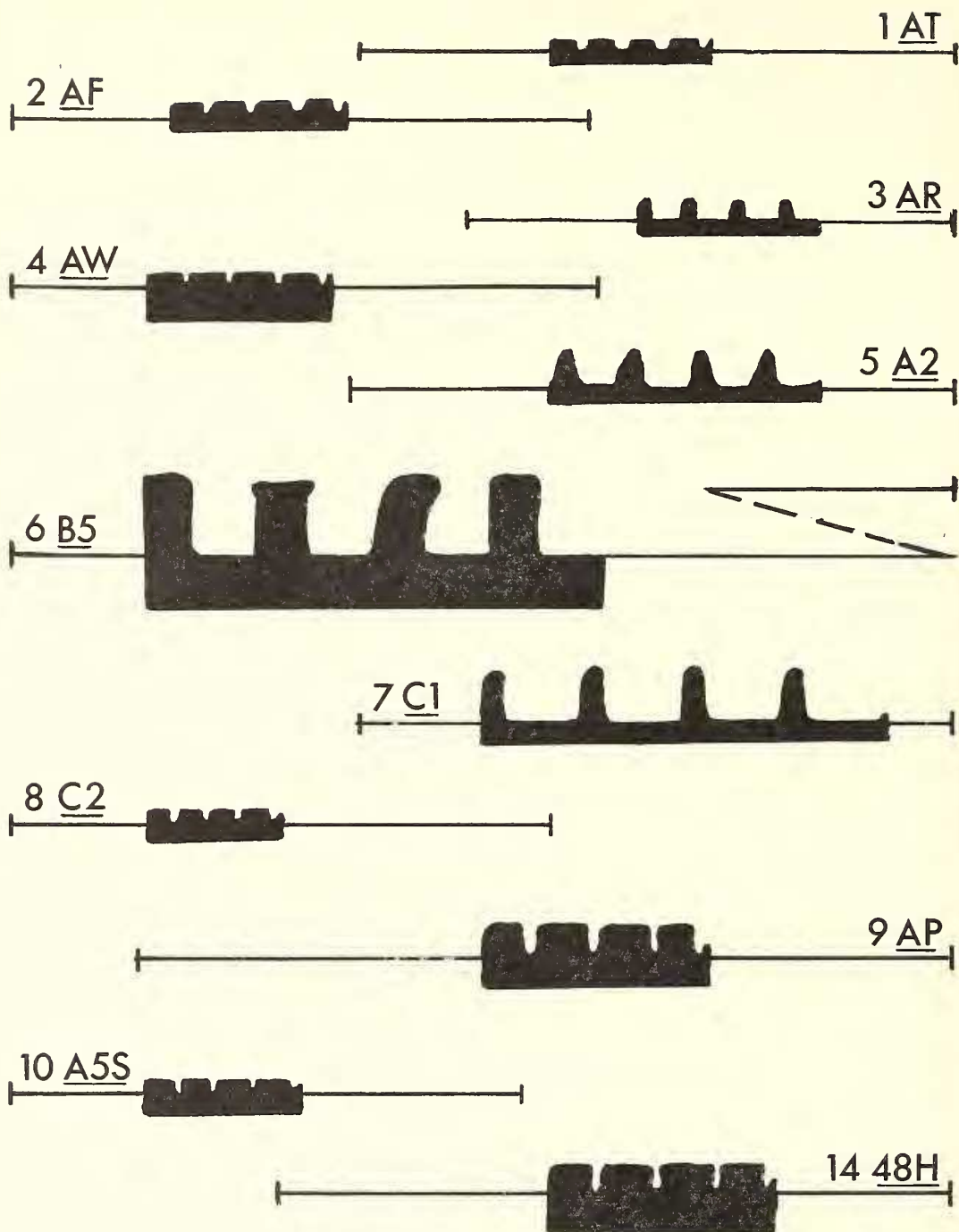
- (a) Well-preserved specimens of selected type, i.e. unambiguous specimens of biorecord.
- (b) Extreme specimens of biorecord, well preserved.
- (c) Possible extreme specimens, poorly preserved.
- (d) Unambiguous specimens of other types.
- (e) Well-preserved specimens that could be extremes of two or more types present.
- (f) Rare specimens that could belong to the biorecord or to any other type present.

These may be aberrants, e.g. monolete, aborted, etc., or even specimens of otherwise unrepresented 'species'.

3. Make detailed measurements and analysis of first unselected 100 specimens from categories 2 (a), (b), and (c), and test for homogeneity in the chief characters.

BIORECORDS CRET 26 23 GB SPOR

The following biorecords are set out with sample data and diagnosis in normal type and intended for data storage; description, preservation, and distinction, etc., which are in small type (not for storage), are items that are usually given for species and are possibly helpful to other workers, but in theory if the stored data has been perfectly prepared they should not be necessary. The title heading and reference line for a biorecord (e.g. 1 CICATR AT) consists of (a) a serial number which outside this paper would be preceded by an identifier such as author initials, (b) an informal (but stored) classification guide, and (c) an author's working reference printed in italics to indicate that it is a 'non-search' item. Holotypes are not mentioned in the text because they are not necessary, but in case they are required later they are marked as designated specimens in the relevant plate explanations.



TEXT-FIG. 1. Diagram of the character 'four adjacent muri and lumina' for each of the biorecord spores, $\times 2,000$. The line in each case represents the mean diameter of the spore to the same scale.

The heading of this section is in the form of a suggestion for data handling and storage; the figures '26 23' stand for the time division 'Tithonian' to Hauterivian Ages/Stages, both inclusive. The Ages/Stages are those used in the 'Fossil Record' (Harland *et al.* 1967), numbered consecutively back from Recent; and they may, we suggest, be used for storage of data and for reference without hierarchical complications (see Hughes *et al.* 1968).

The graded comparisons (cfA., cfB.) used throughout follow our previous scheme (Hughes and Moody-Stuart 1967*b*, p. 353).

1 CICATR AT

Plate 13, figs. 1–12; text-fig. 1

Record sample. Warlingham Borehole (* see p. 97 below), depth 1,998 ft. (see also Event 3 CICATR); greenish-grey banded silty clay, general size of coarse fraction $45\ \mu$. Preparation V067: 60 min. cold conc. HNO_3 , shaken, mineral separation, short centrifuging. Palynologic facies: spores compressed, little damage, little corrosion; 8% other pollen, 2% *Classopollis*, 1% bisaccates, 29% other 'ferns' (incl. 2% *Trilobosporites*), 59% *Cicatricosisporites* (compr. 13% AT, 41% biorecord 2 CICATR AF, 5% indet.); total fern spore size index 12:77:11; many spore-sized plant fragments.

Diagnosis (100 specimens; V067/1,3; 29 02 68). Miospore, trilete, gross maximum diameter mean $44.5\ \mu$, standard deviation $5.3\ \mu$ (100); proximal face thin, plano-convex; distal face convex. Laesura three-quarters radius, lips simple membranous, height $4\text{--}5\ \mu$. Exine $1(2\ \mu)2.5$ including murus (81), radial equatorial exine $1.5(2.5\ \mu)4$ (85). Sculpture positive/negative (Pl. 13, figs. 1, 2): three interrarial sets of sub-parallel muri, height $0.5(1.1\ \mu)1.5$ (97), width $1.0(1.8\ \mu)2.5$ (100); four adjacent muri and lumina in a width of $7(11.9\ \mu)17$, standard deviation $1.54\ \mu$, coefficient of variation 12.9%; distal configuration, polar triangle with concave sides (Pl. 13, fig. 5), radial lumen.

Description. Smooth concave contact area, maximum diameter $10(21\ \mu)40$ (53 specimens). Ratio of mean radial equatorial to normal exine thickness 1.2. Amb subtriangular, sides may be concave (Pl. 13, fig. 5) despite convex distal surface. Muri slightly sinuous at junctions that occur mainly in radial equatorial areas. Thickness of interrarial exine (excl. murus) $0.8(1.2\ \mu)1.5$ (41); because of this thin exine, folding and rupturing of exine are controlled by alignment of muri. In equatorial view, mural sets curve distally between radial equatorial areas, due to distal configuration. Observed limits of gross maximum diameter $32\text{--}60\ \mu$, coefficient of variation 12%. Specimens in polar aspect 47%, equatorial 29%.

Preservation and compression. Thin proximal face may rupture; splitting may occur along radial lumen and adjacent laesura. Thin exine may fold between muri, thus reducing width of 4 muri and lumina, and making equatorial amb concave. In some specimens regular 'drillings' widen murus (Pl. 13, fig. 9).

Distinction local. Biorecord 2 CICATR AF (from same sample) has negative sculpture and no radial lumen. 3 CICATR AR has positive sculpture and wide lumina. 4 CICATR AW has wider muri. *Ruffordia goepperti* (spores) Hughes and Moody-Stuart 1966 are larger, and have wider lumina.

2 CICATR AF

Plate 14, figs. 1–12; text-fig. 1

Record sample. Warlingham Borehole, depth 1,998 ft.; details as in biorecord 1 above.

Diagnosis (100 specimens; V067/1; 29 02 68). Miospore, trilete, gross maximum diameter mean $42.8\ \mu$, standard deviation $5.6\ \mu$ (100); contact areas unsculptured,

plano-convex, proximal face about $2.5\ \mu$ thick (Pl. 14, fig. 10); distal face convex. Laesura two-thirds radius, lips simple, height $3\text{--}4\ \mu$. Exine (incl. murus) $1.5(2\ \mu)3$ thick (99), radial equatorial exine $1.5(3.5\ \mu)6.5$ (90), ratio radial/interradial $1.0(1.7)2.6$ (87 specimens). Sculpture negative (canalliculate) distal and equatorial; straight parallel lumina form 3 interradial sets (of variable number) and alternating in the radial areas; lumen depth (= murus height) $1.0(1.2\ \mu)2.0$ (80); flat-topped murus $2.0(2.2\ \mu)3.0$ wide (100); width of 4 adjacent lumina and muri $9.0(13.1\ \mu)18$ (100), standard deviation $1.94\ \mu$, coefficient of variation 14.8%; distal configuration triangle with straight sides (Pl. 14, fig. 9), or sub-parallel lumina (Pl. 14, figs. 7, 8).

Description. Amb triangular. Maximum diameter of unsculptured area $9(19\ \mu)30$ (70 specimens). Rigidity of spore due to relatively thick exine with narrow ($1\ \mu$) lumina. Radius not crossed by lumina, radial equatorial exine particularly rigid and may be slightly thickened. Muri have sharp rectangular profile. Occasional tetrads seen and 1 monoete specimen. Observed limits of maximum diameter 26–60 μ , coefficient of variation 13%. Specimens in polar aspect 38%, equatorial aspect 34%.

Preservation and compression. When murus outline is not rectangular, this is probably due to exine 'softening' of edges of lumina (Pl. 14, fig. 10).

Distinction local. Biorecords 1 CICATR AT and 4 CICATR AW have radial lumen. 9 CICATR AP is larger in all dimensions.

3 CICATR AR

Plate 15, figs. 1–13; text-fig. 1

Record sample. Warlingham Borehole, depth 1,873 ft. 8 in.; medium grey silty clay, general size of coarse fraction $20\ \mu$, little carbonate, much mica up to $10\ \mu$; plant frag-

EXPLANATION OF PLATE 13

Magnification $\times 1,000$.

Figs. 1–12. Biorecord 1 CICATR AT. 1–3, Designated specimen, proximal aspect, low, mid, and high focus; V067/1, OR 48.8 116.9. 4–5, Distal aspect, low and high focus; V067/1, OR 50.7 119. 6, Equatorial aspect; V067/3, OR 43.7 121.9. 7, Proximal aspect; V067/3, OR 45.1 122.9. 8, Large specimen, high focus; V067/1, OR 38.1 116.9. 9, Distal aspect, high focus; V067/1, OR 36.4 120.2. 10, Distal aspect, high focus; V067/3, OR 36.5 119.3. 11–12, Equatorial aspect, high and low focus; V067/1, OR 55.2 116.4.

EXPLANATION OF PLATE 14

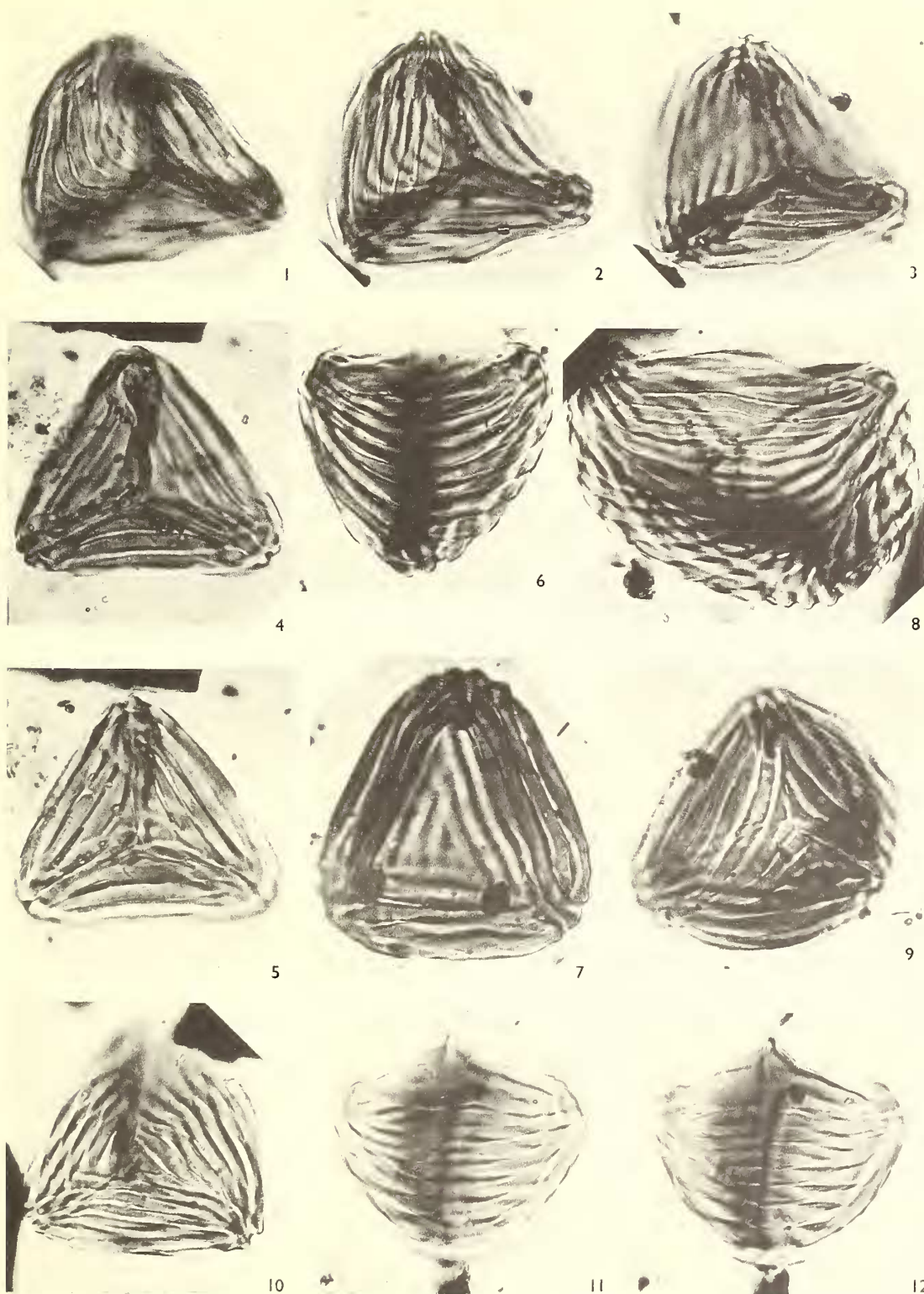
Magnification $\times 1,000$.

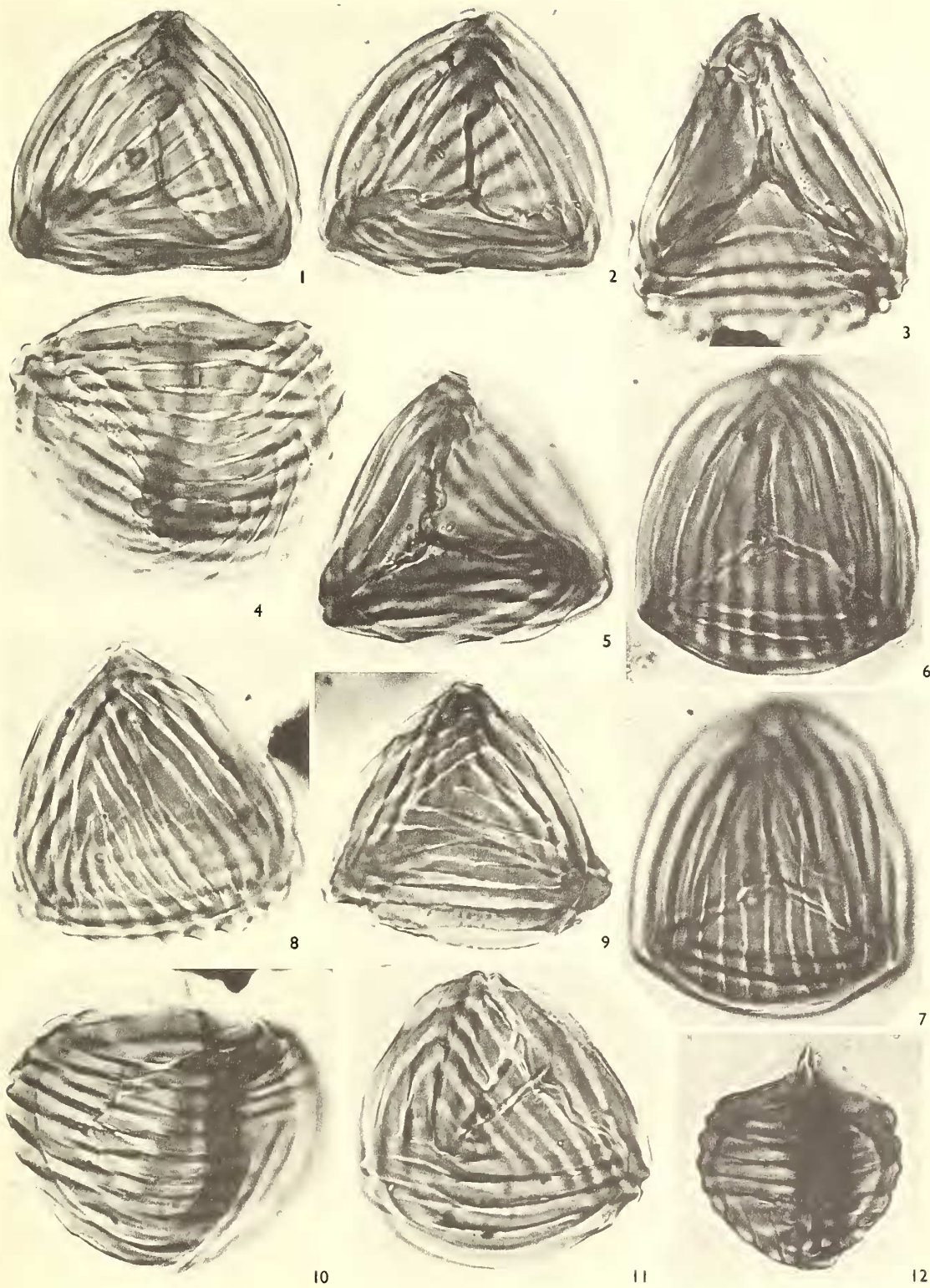
Figs. 1–12. Biorecord 2 CICATR AF. 1–2, Designated specimen, proximal aspect, low and high focus; V067/6, OR 48.5 112. 3, Proximal aspect, high focus; V067/1, OR 50.4 119.8. 4, Oblique aspect, low focus; V067/1, OR 44.6 112.2. 5, Proximal aspect, high focus; V067/1, OR 50 119.8. 6–7, Distal aspect, low and high focus; V067/6, OR 33.7 127.7. 8, Distal aspect; V067/1, OR 39.8 122.5. 9, Distal aspect; V067/1, OR 37.3 121. 10, Equatorial aspect; V067/6, OR 55 120.4. 11, Oblique aspect, low focus; V067/6, OR 50 123.1. 12, Equatorial aspect, mid focus; V067/6, OR 19.1 117.

EXPLANATION OF PLATE 15

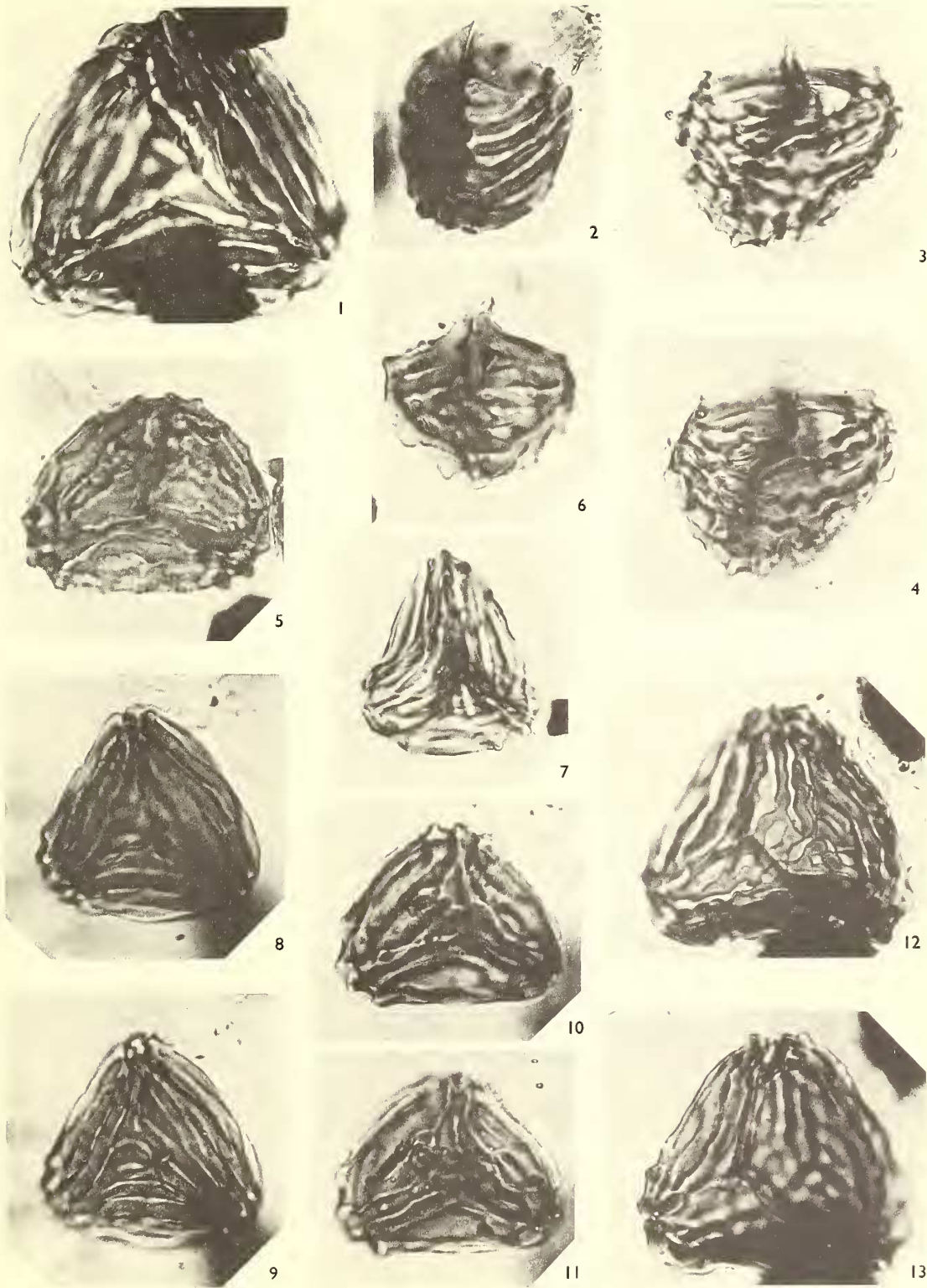
Magnification $\times 1,000$.

Figs. 1–13. Biorecord 3 CICATR AR. 1, Distal aspect; Y528/5, OR 33 122.4. 2, Equatorial aspect; Y528/2, OR 39.3 121.3. 3–4, Equatorial aspect, low and high focus; Y528/2, OR 27.9 113.4. 5, Proximal aspect; Y528/5, OR 37.9 125. 6, Equatorial aspect; Y528/4, OR 39.3 117.3. 7, Oblique aspect, high focus; Y528/2, OR 43.7 119.9. 8–9, Distal aspect, low and high focus; Y528/2, OR 38.7 114.6. 10–11, Distal aspect, low and high focus; Y528/4, OR 28.7 110.9. 12–13, Designated specimen, proximal aspect, low and high focus; Y528/5, OR 27 117.





HUGHES and MOODY-STUART, Early Cretaceous miospore biorecords



ments, regular bedding. Preparation Y528: 30 min. cold conc. HNO_3 , mineral separation. Palynologic facies: some fern spores in good condition, but full range of corrosion and pale fragments, reworking suspected, many small wood fragments; 17% other pollen, 33% *Classopollis* (pale), 7% bisaccates (pale), 30% other 'ferns', 13% *Cicatricosisporites* (compr. 4.3% 3 CICATR *AR*, 4.7% cf. *AT/AW*, 1% or less cfA. 14 CICATR *48H* and cfA. 7 CICATR *CI*); total fern spore size index 45:52:03.

Diagnosis (100 specimens; Y528/2,3,4; 10 01 68). Miospore, trilete, gross maximum diameter mean 36.0μ , standard deviation 5.45μ (100); proximal face plano-concave, distal convex. Laesura medium long, lips simple membranous $2-4 \mu$ high. Sculpture positive, no radial murus. Exine (excl. murus) interrational $0.5(0.8 \mu)1.3$ (70), and radial $0.5(0.9 \mu)1.4$ (71). Distal and equatorial areas bear 3 interrational sets with 4(6)10 (84) sub-parallel muri of height $1.1(1.6 \mu)3.2$ (98), width $0.6(1.1 \mu)2.0$ (94); width of 4 adjacent muri and lumina $10.0(13.5 \mu)17.0$ (99), standard deviation 2.09μ . Proximal face unsculptured triangle (Pl. 15, fig. 12) of height $12(19 \mu)28$ (71), distal configuration symmetrical concave-sided polar triangle.

Description. Approximately 50% of specimens have sinuous and undulose muri, and in 20% muri anastomose interrationally. Polar views show 3 or 4 muri in profile crossing radial amb perpendicularly. Eight specimens have muri flattened (Pl. 15, fig. 1) interrationally to apparent width $1.0(2.0 \mu)3.2$. Observed limits of gross maximum diameter $24-5 \mu$, coefficient of variation 15.1%; coefficient for width of 4 muri and lumina 14.7%. Aspect of specimens, 16% distal, 18% proximal, 33% equatorial.

Preservation. Mural height in some specimens may have been reduced by corrosion.

Distinction local. Biorecord 1 CICATR *AT* has closer, lower, more numerous muri. 5 CICATR *A2* is larger and has higher, straighter, more widely spaced muri. 14 CICATR *48H* has negative sculpture, thicker exine, wider muri. *Ischyosporites* spp. have more perfect and uniform distal mural reticulum. *Ruffordia goepperti* (spores) are larger (mean 50μ), and have lower muri.

4 CICATR *AW*

Plate 16, figs. 1-12; text-fig. 1

Record sample. Warlingham Borehole, depth 1,945 ft.; medium grey silty clay, bedded, general size of coarse fraction 20μ . Preparation V419: 25 min. cold conc. HNO_3 , mineral separation, short centrifuging. Palynologic facies: many spores in good condition, some pale and some corroded, *Botryococcus* abundant; 32% other pollen, 19% *Classopollis*, 14% bisaccates, 32% other 'ferns', 3% *Cicatricosisporites* (compr. 3% 4 CICATR *AW*, also present cfA. 1 CICATR *AT*, cfA. 3 CICATR *AR*, cfB. 7 CICATR *CI*); total fern spore size index 47:39:14.

Diagnosis (100 specimens; V419/1; 08 04 68). Miospore, trilete, gross maximum diameter mean 43.3μ , standard deviation 5.58μ (100); proximal face plano-convex, distal convex. Laesura medium long, lips simple membranous $2-5 \mu$ high. Sculpture negative, no radial murus. Exine thickness (incl. murus), radial $2.0(3.7 \mu)12.0$ (88), interrational $1.4(2.3 \mu)5.6$ (87). Three interrational sets of sub-parallel muri of height $1.0(1.1 \mu)2.5$ (79), and width $1.2(2.4 \mu)4.0$ (100); width of 4 adjacent muri and lumina $10.0(13.4 \mu)19.0$ (100); distal configuration symmetrical concave-sided polar triangle, proximal sculptured.

Description. Gross maximum diameter limits 26–69 μ , coefficient of variation 12.8%; coefficient of variation of width of 4 muri and lumina 34.5%. Radial exine thickening distinct in a few specimens that could perhaps be separated. Aspect of specimens, proximal 22%, distal 19%, equatorial 24%; 1 monolete specimen seen.

Distinction local. Biorecord 1 CICATR *AT* is of the same size and configuration but has narrower muri. 2 CICATR *AF* has no radial lumen. 3 CICATR *AR* has positive sculpture, thinner exine, and is smaller.

5 CICATR *A2*

Plate 17, figs. 1–11; text-fig. 1

Record sample. Warlingham Borehole, depth 1,843 ft.; medium grey silt, general size of coarse fraction 100 μ , much mica up to 50 μ ; plant fragments; disturbed, small lenses. Preparation V016: 10 min. warm conc. HNO_3 , shaken, mineral separation. Palynologic facies: spores in good condition, fragments of unmacerated wood; 19% other pollen, 7% *Classopollis*, 14% bisaccates, 40% other ‘ferns’, 20% *Cicatricosisporites* (compr. 1% 5 CICATR *A2*, 10% cf. *AT/AW*, 5% 14 CICATR *48H*, 2% cf. *A*. 3 CICATR *AR*, also present cf. *A*. 6 CICATR *B5*); total fern spore size index 25:53:22.

Diagnosis (100 specimens; V016/1,2,3,4; 29 02 68). Miospore, trilete, gross maximum diameter mean 44.8 μ , standard deviation 6.38 μ (100); proximal face plano-concave, distal convex. Laesura medium length, lips simple membranous low. Exine (excl. murus) interradiol 0.5(1.1 μ)1.8 (71). Sculpture positive, radial lumen; distal and equatorial areas bear 3 interradiol sets each with 3(5)10 (96) sub-parallel muri of height 2.0(3.2 μ)5.5 (94), width 1.5(2.7 μ)4.0 (89); width of 4 adjacent muri and lumina 12.0(20.0 μ)30.0 (90), standard deviation 6.7 μ ; distal configuration symmetrical concave-sided polar triangle (Pl. 17, fig. 2), with some muri coalescing interradiol (Pl. 17, fig. 7); proximal unsculptured.

Description. Muri may fold down (Pl. 17, fig. 3), increasing apparent width of murus up to 6 μ , and decreasing apparent height of murus and width of lumen, which is 0.5(2.5 μ)7.0 (90). Murus broad-based in section, making murus-width a somewhat uncertain measurement. Downfolding of exine (Pl. 17, fig. 9) between muri leads to highly variable ‘width of 4 muri and lumina’, coefficient of variation 33%. Observed limits of gross diameter 32–59 μ , coefficient of variation 14.2%. Aspect of specimens, 19% equatorial, 29% proximal, 19% distal.

EXPLANATION OF PLATE 16

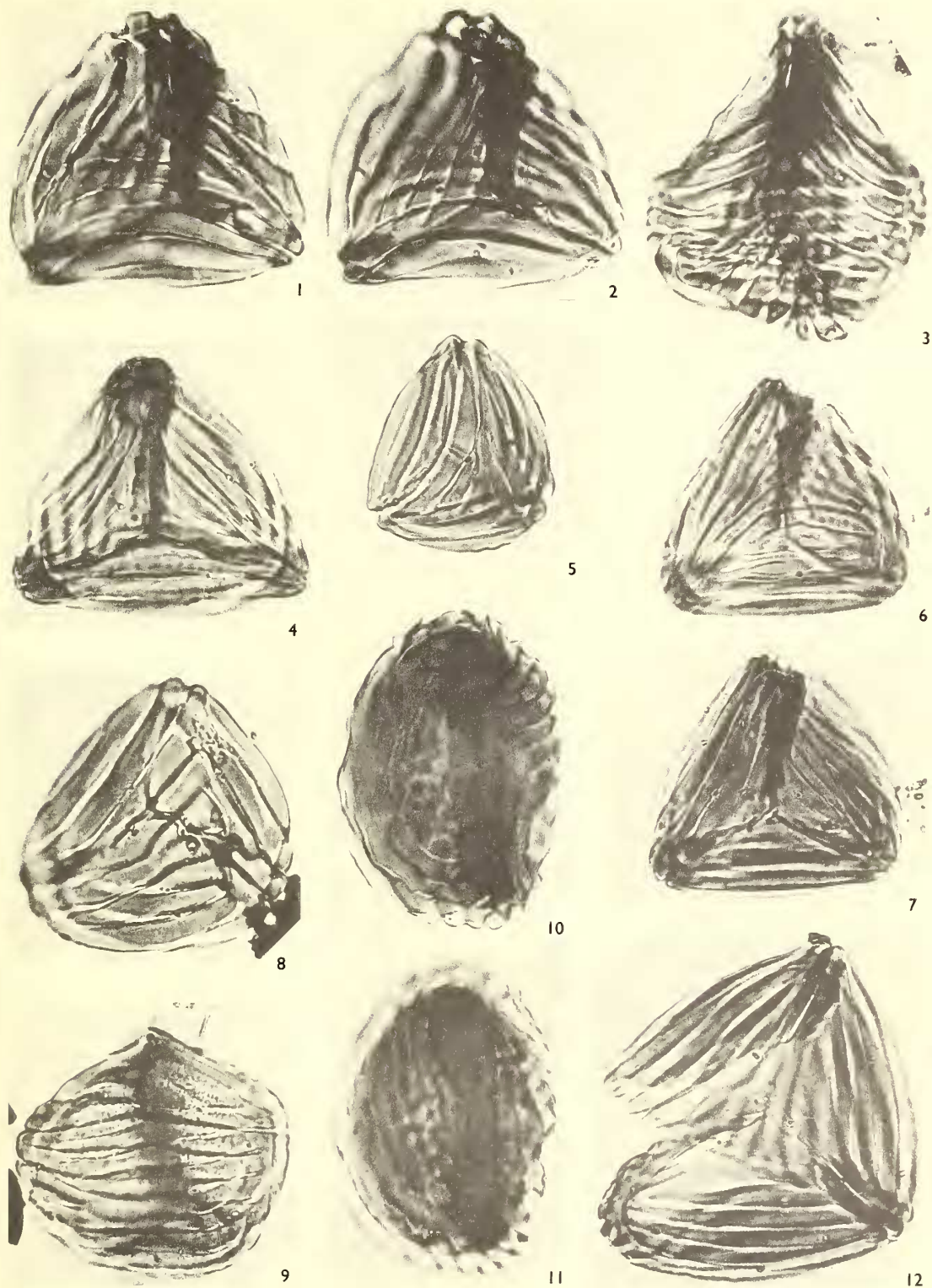
Magnification $\times 1,000$.

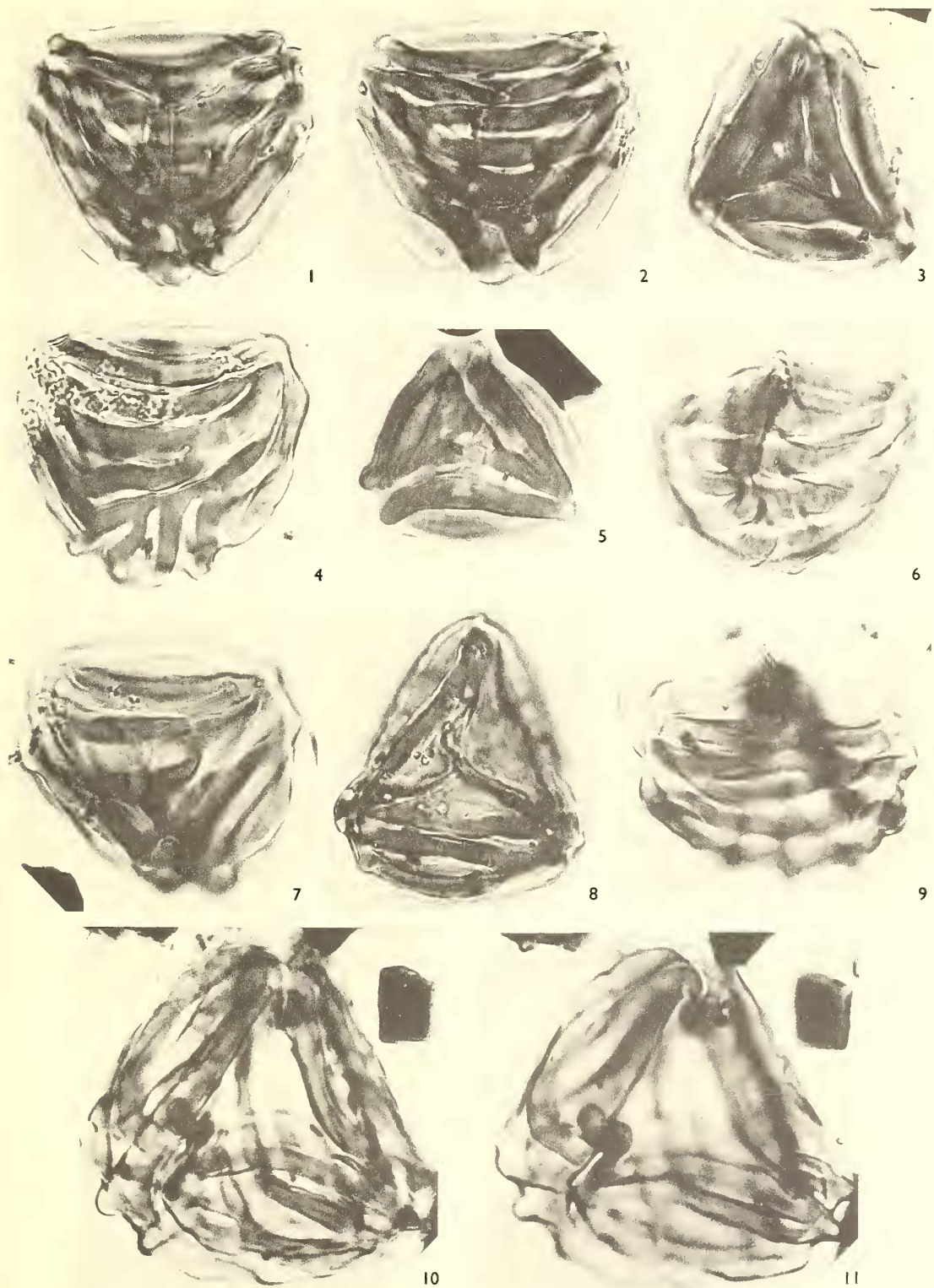
Figs. 1–12. Biorecord 4 CICATR *AW*; prep. V419/1. 1–2, Oblique proximal, low and high focus; OR 44.4 115.9. 3, Oblique equatorial, OR 23.1 117.8. 4, Designated specimen, proximal; OR 32.2 122.5. 5, Distal aspect, high focus; OR 29.5 114.8. 6–7, Proximal aspect, low and high focus; OR 42.5 126.9. 8, Proximal aspect, low focus; OR 22.1 125.2. 9, Equatorial aspect; OR 37.1 116.2. 10–11, Monolete specimen, low and high focus; OR 28.8 115. 12, Proximal aspect, torn; OR 42.3 121.5.

EXPLANATION OF PLATE 17

Magnification $\times 1,000$.

Figs. 1–11. Biorecord 5 CICATR *A2*. 1–2, Designated specimen, distal aspect, low and high focus; V016/4, OR 38.4 122. 3, Distal aspect, high focus; V016/1, OR 43.2 120.2. 4, Distal aspect; V016/3, OR 23.3 113.1. 5, Distal aspect; V016/1, OR 40.4 123. 6, Equatorial aspect, low focus; V016/4, OR 43.7 128.6. 7, Distal aspect, high focus; V016/4, OR 34.3 112.8. 8, Proximal aspect; V016/1, OR 40.3 109.8. 9, Equatorial aspect, low focus; V016/3, OR 31.1 110.7. 10–11, Proximal aspect, low and high focus; V016/1, OR 24.3 111.5.





Distinction local. Biorecord 3 CICATR *AR* is smaller with lower and thinner muri. 7 CICATR *CI* (*Cic. lucifer* H. and M-S. 1967b) has narrow-based muri and wider lumina, a radial murus, and distal configuration of symmetrical straight-sided polar triangle. 6 CICATR *B5* is larger with higher and thicker muri, thicker exine and proximal sculpture. 15 CICATR *A3* is larger in all dimensions.

6 CICATR *B5*

Plate 18, figs. 1–8; text-fig. 1

Record sample. Warlingham Borehole, depth 1,834 ft.; light medium grey siltstone, well sorted with general size of coarse fraction $50\ \mu$; lensing and disturbance throughout. Preparation V017: twice warm conc. HNO_3 totalling 1 h., shaken, mineral separation, short centrifuging. Palynologic facies: spores in fair condition, but many broken; 38% other pollen, 4% *Classopollis*, 14% bisaccates, 28% other ‘ferns’, 16% *Cicatricosisporites* (compr. 4% 6 CICATR *B5*, 5% cfA. 5 CICATR *A2*, 4% cfA. 4 CICATR *AW*, etc.); total fern spore size index 13:44:43.

Diagnosis (100 specimens; V017/1,2,3; 26 01 68). Miospore, trilete, gross maximum diameter mean $88.3\ \mu$, standard deviation $13.7\ \mu$ (100); proximal face planar, distal convex. Laesura medium long, lips simple, same height as muri. Sculpture positive. Exine (excl. murus) $2.5(4.2\ \mu)6.0$ (84) measured interradially is of even thickness, giving an apparent total radial thickness $6.0(11.0\ \mu)16.0$ (95), including murus height $3.2(5.7\ \mu)10.0$ (77). Three interradiial sets of $5(8.5)11$ (78) sub-parallel muri occupy proximal, equatorial and distal surfaces, and members of sets coalesce sub-radially (Pl. 18, fig. 8); murus width $2.2(3.4\ \mu)5.0$ (84); width of 4 adjacent muri and lumina $23(33.4\ \mu)44$ (94), standard deviation $5.05\ \mu$. Distal configuration symmetrical straight-sided polar triangle.

Description. Radial lumen usually absent. ‘Drillings’ in muri (Pl. 18, fig. 7) occur in 84% of specimens and resulting distortion causes increased apparent murus width $3.0(5.2\ \mu)8.0$ (92), but contrast Plate 18, fig. 8. True murus height not always measurable (Pl. 18, fig. 2) because of exine thickness which is $2.0(5.1\ \mu)7.2$ (39); contrast with Plate 18, fig. 1. In distal configuration, only 2 specimens have symmetrical concave-sided polar triangle, and 2 specimens sub-parallel muri. Range of gross maximum diameter $54\text{--}103\ \mu$, coefficient of variation 15.5%; coefficient for width of 4 muri and lumina 15.1%. Specimens in equatorial aspect 9%, proximal 29%, distal 38%.

Preservation. Most specimens inflated, 25% show corrosion, 37% torn; stronger oxidation than usual was necessary to clear sufficiently the opaque thick exine.

Distinction local. Biorecord 5 CICATR *A2* is smaller, has unsculptured proximal face, and always has radial lumen. 9 CICATR *AP* is smaller has negative sculpture, and will not be confused with *B5* when that spore is in good condition. 15 CICATR *A3* has fewer, wider muri.

7 CICATR *CI*

Text-fig. 1

Record sample. Warlingham Borehole, depth 1,757 ft.; for all details see record of *Cicatricosisporites lucifer* Hughes and Moody-Stuart (1967b).

8 CICATR C2

Plate 19, figs. 1-11; text-fig. 1

Record sample. Warlingham Borehole, depth 1,740 ft. 6 in.; medium grey sandy silt, general size of coarse fraction $30\ \mu$, mica flakes to $150\ \mu$; small plant fragments, thin banding. Preparation V416: 25 min. cold conc. HNO_3 , mineral separation, short centrifuging. Palynologic facies: many spores in good condition, few pale and torn specimens, little corrosion, medium and small unmacerated wood fragments; 18% other pollen, 13% *Classopollis* (pale), 23% bisaccates (pale), 30% other 'ferns', 16% *Cicatricosisporites* (compr. 1% 8 CICATR C2, 5% cfA. 7 CICATR C1, 5% cfA. 4 CICATR AW, 1% 9 CICATR AP, 1% 10 CICATR AS5, 1% cfA. 5 CICATR A2, and others); total fern spore size index 08:50:42.

Diagnosis (100 spccimens; V416/1,2,3,4,5,7,8; 29 02 68). Miospore, trilete, gross maximum diameter mean $39.9\ \mu$, standard deviation $5.03\ \mu$ (100); proximal face plano-convex, distal convex. Laesura medium length, lips simple, $2-4\ \mu$ high. Sculpture negative (canaliculate), proximal, equatorial, and distal; straight parallel lumina form 3 interrarial sets asymmetrically developed on distal face in 50% of specimens; flat-topped murus (Pl. 19, figs. 4, 5), width $1.2(1.7\ \mu)2.8$ (99), and lumen depth $0.5(1.1\ \mu)1.3$ (34); width of 4 adjacent lumina and muri $7.0(9.9\ \mu)15$ (99), standard deviation $2.67\ \mu$, coefficient of variation 27.1%. Interrarial exine thickness (incl. murus) $1.3(2.2\ \mu)3.0$ (93); unsculptured elongate radial equatorial extensions with radial dimension $1.2(4.1\ \mu)6.5$ (88), width in equatorial plane $2.5(6.4\ \mu)13$ (84) (Pl. 19, figs. 6, 11), and 2(5)7 (71) members from each of 2 adjacent equatorial sets of lumina terminating at base of extension; radial equatorial exine thickness $4.0(6.8\ \mu)9.0$ (98), ratio radial/interrarial $1.7(3.1)5.3$ (93).

Description. Interrarial amb convex. Observed limits of gross maximum diameter 29-52 μ , coefficient of variation 12.6%. 18% of specimens show unsculptured area $6.0(13.9\ \mu)20$. Only 5% of specimens have radial extensions that are unusually wide or small. Distal configuration: straight-sided triangle 27%, concave-sided triangle 25%, sub-parallel muri 38% (73). Aspect of specimens, proximal 29%, distal 31%, equatorial only 9% presumably because of presence of radial extensions.

EXPLANATION OF PLATE 18

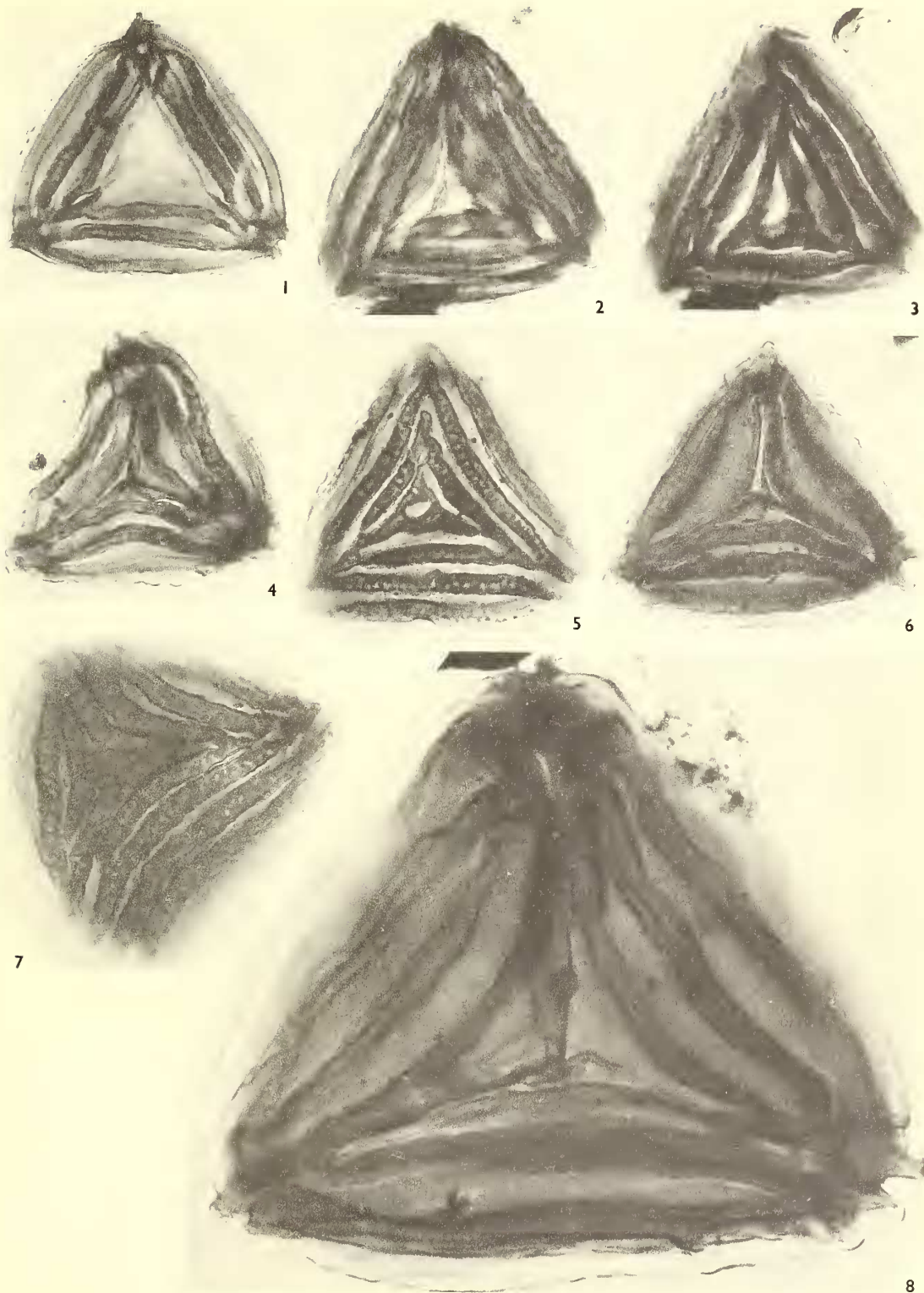
Magnification of Fig. 8 $\times 1,000$; all others $\times 500$.

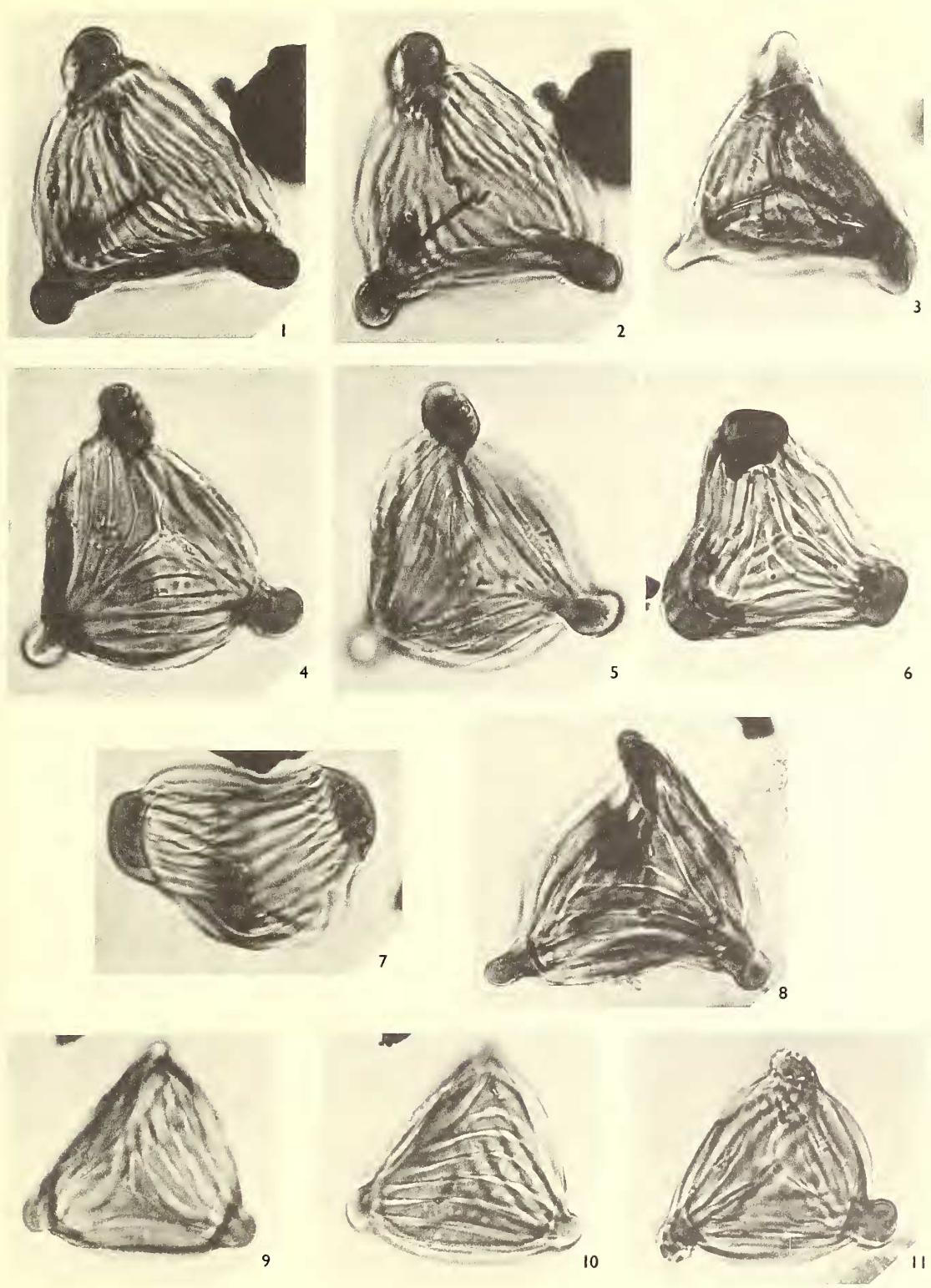
Figs. 1-8. Biorecord 6 CICATR B5. 1, Distal aspect, high focus; V017/2, OR 44.5 109.2. 2-3, Distal aspect, low and high focus; V017/2, OR 39.2 111.9. 4, Proximal aspect; V017/2, OR 38.9 112. 5, Distal aspect; V017/3, OR 30.9 118.3. 6, Proximal aspect; V017/2, OR 31.2 119.7. 7, Oblique showing drillings; V017/3, OR 41.9 123.8. 8, Designated specimen, proximal aspect; V017/3, OR 31.1 117.4.

EXPLANATION OF PLATE 19

Magnification $\times 1,000$.

Figs. 1-11. Biorecord 8 CICATR C2. 1-2, Proximal aspect, low and high focus; V416/1, OR 20.4 118.2. 3, Proximal aspect; V416/4, OR 55.8 115. 4-5, Designated specimen, distal aspect, low and high focus; V416/7, OR 51.4 116.3. 6, Distal aspect, low focus; V416/4, OR 57.3 114.8. 7, Equatorial aspect, high focus; V416/4, OR 38.8 114.6. 8, Distal aspect, low focus; V416/3, OR 22 115.1. 9-10, Distal aspect, low and high focus; V416/7, OR 35.4 123.2. 11, Proximal aspect, low focus; V416/5, OR 46.5 123.2.





Preservation and compression. In natural compression, radial equatorial extensions twist readily on relatively thin spore body; of 20 fractured specimens (= 20% of total), 18 were torn parallel to base of extension. Corrosion often appears to affect radial extension but not spore body, and vice versa.

Distinction local. Biorecord 7 CICATR *C1* has positive sculpture, and the radial extensions arise from single mural intersections. 9 CICATR *AP* is larger, has thicker exine, wider muri, and sculptured radial extension (if any). 13 CICATR *C2L* is larger in all dimensions.

9 CICATR *AP*

Plate 20, figs. 1–7; text-fig. 1

Record sample. Warlingham Borehole, depth 1,740 ft. 6 in.; all details given under 8 CICATR *C2*.

Diagnosis (100 specimens; V416/2,3,4,5,6; 29 02 68). Miospore, trilete, gross maximum diameter mean $60.4\ \mu$, standard deviation $8.9\ \mu$ (100); proximal face plano-convex, distal convex. Laesura medium length, flanked by deep lumen, lips simple, low (Pl. 20, figs. 2, 3). Exine thickness radial equatorial (incl. murus) $4.0(9.0\ \mu)16.0$ (98), interr radial $2.5(4.5\ \mu)7.5$ (100), ratio radial/interradial $1.0(2.0)4.0$ (98). Sculpture negative, radial lumen always absent; proximal, equatorial, and distal surfaces bear 3 interr radial sets of regular sub-parallel lumina of depth $1.2(2.4\ \mu)3.2$ (37), $2.0(3.3\ \mu)5.0$ (99) apart; width of 4 adjacent lumina and muri $12.0(16.7\ \mu)23.0$ (100), standard deviation $4.4\ \mu$, coefficient of variation 26.2% (Pl. 20, fig. 6); lumina of adjacent sets do not coalesce; distal configuration, symmetrical straight-sided polar triangle to sub-parallel.

Description. Observed limits of gross maximum diameter 45–83 μ , coefficient of variation 14.7%. Of spores with sub-parallel distal configuration, half had muri perpendicular (Pl. 20, fig. 1) to a radius, and half parallel to a radius. Equatorial aspect 21% of specimens, proximal 20%, and distal 24%. Thick radial exine due to thickening of internal layers of exine; radial equatorial sculpture not modified.

Preservation. 50% of all specimens were torn, 25% showed corrosion (Pl. 20, fig. 4), and 10% were 'drilled' (see description of biorecord 14 CICATR *48H*).

Distinction local. Biorecord 6 CICATR *B5* is larger, with wider, deeper lumina (i.e. positive sculpture); 12 CICATR *APP* is larger. 8 CICATR *C2* is smaller in all dimensions, and has unsculptured radial equatorial extensions. 14 CICATR *48H* has exine of even thickness and radial lumen. *Pelletieria valdensis* (spores) are similar but larger (Hughes and Moody-Stuart 1966).

10 CICATR *A5S*

Plate 21, figs. 1–12; text-fig. 1

Record sample. Warlingham Borehole, depth 1,740 ft. 6 in.; all details given under 8 CICATR *C2*.

Diagnosis (100 specimens; V416/2,4,6,7,8; 29 02 68). Miospore, trilete, gross maximum diameter mean $37.8\ \mu$, standard deviation $5.66\ \mu$ (100 specimens); proximal face plano-convex, distal very convex. Laesura medium short, lips simple membraneous, low. Sculpture negative; not more than 1 radial lumen. Exine thickness (incl. murus), inter-radial $2.0(2.8\ \mu)3.9$ (97), radial $2.0(2.9\ \mu)4.1$ (92). Proximal, equatorial, and distal surfaces bear sub-parallel lumina, depth $0.5(1.1\ \mu)2.1$ (71), and $1.5(2.2\ \mu)3.2$ (100) apart; width of 4 adjacent lumina and 'muri' $7.3(11.5\ \mu)16$, standard deviation $1.78\ \mu$ (100). Proximal configuration of concentric triangles; equatorially 2 to 4 circular lumina that

may be truly continuous (11%; Pl. 21, figs. 1, 2), or inter-finger in 1 radial area (47%; Pl. 21, fig. 6), or be broken by 1 radial lumen (42%); distal configuration sub-parallel.

Description. Spore appears spherical; this is supported by distribution of spore aspects, 36% polar (11% proximal, 25% distal), 31% equatorial, 33% oblique. Sculpture may be asymmetrical. Coefficient of variation 15.0% for gross diameter, 15.5% for width of 4 lumina and 'muri'.

Preservation. Most specimens inflated; only 14% show any corrosion, but 31% are torn; this is similar for other spores of this assemblage.

Distinction local. *Schizaeopsis americana* (spores) has circular lumina, but is larger and has smaller sculptural elements. Biorecord 16 CICATR *A5H* is larger and has proximal configuration with lumina of each interrational set parallel to one branch of laesura.

14 CICATR 48H

Plate 22, figs. 1–12; text-fig. 1

Record sample. Sample H48/16 (TQ 88721288), prominent 6-ft. silt bed (upper part), 20 ft. above cliff base, 150 m. east of Cliff End Point, 4 miles east of Hastings; pale grey silt, no lamination, few plant fragments. Preparation N016: 12 h. Schulze solution, cold, not renewed; mineral separation. Palynological facies: spores in good condition, plus small pale indet. fragments, cuticle, spore-masses, megaspores; 3% bisaccates, 82% other 'ferns', 15% *Cicatricosisporites* (compr. 13% cfA. 14 CICATR 48H, 2% cfA. 1 CICATR AT); total fern spore size index 09:43:48.

Diagnosis (100 specimens; N016/1; 29 02 68). Miospore, trilete, gross maximum diameter mean 50.0 μ , standard deviation 5.8 μ (100 specimens); proximal face plano-convex, distal convex. Laesura long to medium, lips simple membranous. Sculpture

EXPLANATION OF PLATE 20

Magnification $\times 1,000$.

Figs. 1–7. Biorecord 9 CICATR *AP*. 1–2, Designated specimen, proximal aspect, low and high focus; V416/2, OR 32.8 118.1. 3, Proximal aspect, high focus; V416/6, OR 49.3 120.2. 4, Extreme specimen; V416/2, OR 45.7 122.8. 5, Proximal aspect, high focus; V416/6, OR 35.4, 111.6. 6, Distal aspect, high focus; V416/6, OR 53.3 120.3. 7, Equatorial aspect; V416/4, OR 25.4 122.6.

EXPLANATION OF PLATE 21

Magnification $\times 1,000$.

Figs. 1–12. Biorecord 10 CICATR *A5S*. 1–2, Designated specimen, distal aspect, low and high focus; V416/8, OR 24.2 118.1. 3, Equatorial aspect, high focus; V416/8, OR 50.6 111.4. 4–5, Equatorial aspect, low and high focus; V416/7, OR 38.9 110.9. 6, Equatorial aspect; V416/6, OR 22.3 115.4. 7–8, Distal aspect, low and high focus; V416/6, OR 28.6 112.5. 9–10, Distal aspect, low and high focus; V416/4, OR 29.6 121. 11–12, Distal aspect, low and high focus; V416/6, OR 22.8 118.

EXPLANATION OF PLATE 22

Magnification $\times 1,000$.

Figs. 1–12. Biorecord 14 CICATR 48H; N016/1. 1–3, Designated specimen, proximal aspect, low, mid, and high focus; OR 27.4 111.3. 4, Distal aspect, high focus; OR 33.1 121.7. 5, Equatorial aspect, low focus; OR 27.2 116.1. 6–7, Proximal aspect, mid and high focus; OR 33.4 120.6. 8, Equatorial aspect, high focus; OR 26.9 116.2. 9, Distal aspect, high focus; OR 32.7 114.9. 10, Distal aspect, low focus; OR 33.1 120.1. 11–12, Distal aspect, high and low focus; OR 29.5 126.6.



HUGHES and MOODY-STUART, Early Cretaceous miospore biorecords